THE FLORISTIC ECOLOGY OF XERIC LIMESTONE PRAIRIES IN KENTUCKY, AND A COMPARISON TO LIMESTONE CEDAR GLADES AND DEEP-SOIL BARRENS

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ABSTRACT

The flora of 18 xeric limestone prairies in the Interior Low Plateaus physiographic province in Kentucky was surveyed and a checklist of vascular plants prepared for each site. Nine of the 18 sites are in the Knobstone Escarpment and Knobs, four in the Mammoth Cave Plateau, two in the Pennyroyal Plain and three in the Outer Blue Grass. Life form, photosynthetic pathway, geographic affinity, conservation status and presence were determined for each taxon. Community coefficients were calculated from site floristic lists, and the physiography, geology and soils associated with each site were documented. The flora of xeric limestone prairies in Kentucky was compared to that of limestone cedar glades of the southeastern United States and of deep-soil barrens of the southwestern Pennyroyal Plain in Kentucky and Tennessee. Three hundred and thirty-five taxa were identified in this plant community type, of which 20 are nonnative and 24 state-listed. Families with the highest number of taxa were Asteraceae (70), Poaceae (32) and Fabaceae (29); genera with the highest number of taxa were *Symphyotrichum* (15), *Panicum* sensu lato (=*Panicum* + *Dichanthelium*) (10), *Carex* (7), *Solidago* (7) and *Hypericum* (6). Intraneous C_3 hemicryptophytes make up the majority of the flora. Community coefficients indicate high similarity among all sites except those in the eastern outer Blue Grass, which belong to a second association or community type. Endemic species, a higher percentage of therophytes (i.e. annuals, especially winter annuals) and a higher number of taxa with western and northwestern geographic affinities distinguish the limestone cedar glade flora from those of xeric limestone prairies and deep-soil barrens.

RESUMEN

La flora de 18 praderas calcáreas xéricas en la provincia fisiográfica Interior Low Plateaus en Kentucky fue estudiada y se preparó un catálogo de plantas vasculares en cada lugar. Nueve de los 18 puntos están en el Knobstone Escarpment y Knobs, cuatro en el Mammoth Cave Plateau, dos en la Pennyroyal Plain, y tries en el Outer Blue Grass. Se determinó el tipo biológico, ruta fotosintética, afinidad geográfica, estado de conservación y presencia de cada taxon. Se calcularon los coeficientes de comunidad a partir de las listas florísticas del punto, y se documentó la fisiografía, geología y suelos asociados con cada punto. La flora de las praderas calcáreas xéricas en Kentucky se compara con la de los claros calcáreos de cedro del Sureste de los Estados Unidos y con la de los eriales de suelos profundos del Suroeste de la Pennyroyal Plain en Kentucky y Tennessee. Se identificaron trescientos treinta y cinco taxa en este tipo de comunidad vegetal, de los que 20 no son nativos y 24 están listados en el estado. Las familias con el mayor número de taxa fueron Asteraceae (70), Poaceae

(32) y Fabaceae (29), los géneros con el mayor número de taxa fueron *Symphyotrichum* (15), *Panicum* sensu lato (=*Panicum* + *Dichanthelium*) (10), *Carex* (7), *Solidago* (7) e *Hypericum* (6). Los hemicriptófitos C_4 característicos de la comunidad forman la mayor parte de la flora. Los coeficientes de comunidad indican alta similitud entre todos los puntos excepto los de Northeastern Blue Grass, que pertenecen a una segunda asociación o tipo de comunidad. Las especies endémicas, un alto porcentaje de terófitos (ej. anuales, especialmente anuales de invierno) y un alto número de taxa con afinidades geográficas occidentales y noroccidentales diferencian la flora de los claros calcáreos de cedro de la de las praderas calcáreas xéricas y eriales de suelos profundos.

INTRODUCTION

Xeric limestone prairies are characterized by high cover of C_4 perennial grasses (*Schizachyrium scoparium*, *Andropogon gerardii*, *Sorghastrum nutans* and *Bouteloua curtipendula*), moderate to steep slopes with south to west aspects and shallow rocky soils derived from calcareous substrates (Baskin & Baskin 2000). In Kentucky, these herbaceous plant communities occur in the western mesophytic forest region (sensu Braun 1950) and are rare at the landscape scale. The flora of xeric limestone prairies in Kentucky has not been adequately characterized, and the soils, geology and physiography associated with this community type have not been documented systematically. Thus, the primary objectives of the present study were to: 1) provide a checklist of vascular plants in xeric limestone prairies in Kentucky based upon field work conducted by the first author; 2) determine the geographic relationships, life forms and photosynthetic pathways of the constituent taxa; and 3) document the soils, geology and physiography associated with xeric limestone prairies in Kentucky. A fourth objective was to further compare xeric limestone prairies to limestone cedar glades and deep-soil barrens, both of which also are developed on calcareous substrates and occur in the western mesophytic forest region.

In their comparison of xeric limestone prairies, limestone cedar glades and deep-soil barrens in the Kentucky Karst Plain and adjacent areas, Baskin et al. (1994) focused primarily on vegetation, edaphic characteristics and origins. Like xeric limestone prairies, deep-soil barrens are characterized by high cover of C_4 perennial grasses (*Schizachyrium scoparium*, *Andropogon gerardii* and *Sorghastrum nutans*). However, deep-soil barrens originated from periodic burning by Native Americans prior to European settlement, whereas xeric limestone prairies resulted from clearing of land for agricultural purposes, overgrazing and subsequent soil erosion (Baskin et al. 1994). Conversely, limestone cedar glades are an edaphic climax community and typically have high cover of the C_4 summer annual grass *Sporobolus vaginiflorus* (Baskin & Baskin 1999).

Baskin and Baskin (2003) published the flora of limestone cedar glades of the southeastern United States, and Chester et al. (1997) published the flora of deep-soil barrens in the southwestern Pennyroyal Plain of Kentucky and Tennessee. By providing a flora of xeric limestone prairies in Kentucky, the current study affords the opportunity for floristic comparisons among these three herbdominated community types. Comparative data on species richness, geographic affinities, photosynthetic pathways, life form and taxonomic distribution of the three respective floras are essential for accurate characterization of these community types and will provide further insight into their ecological differences.

SITE CHARACTERISTICS

A site was defined as a single forest opening (Fig. 1), many of which contained small patches of woody vegetation. In two sample areas (Crooked Creek Barrens and Fort Knox Military Reservation), two forest openings occurred on the same land parcel. However, in both of these properties the two openings are separated by at least 100 m, and thus each opening was considered a site. An attempt was made to determine the exact area of each site using GIS software. However, the large perimeter to area ratios and patches of woody vegetation in many sites prevented accurate measurement. In general, sample sites ranged from less than 0.5 to approximately 2.25 hectares. Site characteristics are summarized in Table 1.

Physiography

In Kentucky, xeric limestone prairies occur in the Blue Grass, Shawnee and Highland Rim sections of the Interior Low Plateaus physiographic province (sensu Quarterman & Powell 1978) (Fig. 2). The Knobstone Escarpment and Knobs subsection of the Blue Grass supports the largest number of xeric limestone prairies in the state, containing nine of the 18 sites surveyed in this study. The relatively high number of xeric limestone prairies in this area is most likely due to the rugged terrain in the region, since moderate to steep slopes with fine-textured soils are particularly susceptible to soil erosion. Xeric limestone prairies also occur in the western (Pine Creek Barrens) and eastern (Crooked Creek Barrens 1 and 2) Outer Blue Grass. In the Shawnee Hills section, all four sample sites (Grayson County Barren, Knight's Barren, Lapland Barrens and Lapland Road Barrens) are located in the Mammoth Cave Plateau. Logan County Glade and Logan County Barrens also are shown in the Mammoth Cave Plateau on the map of Quarterman and Powell map (Fig. 1, page 30). However, we consider them to be in the Pennyroyal Plain subsection of the Highland Rim, which is in agreement with Fenneman (1938, Figure 123, page 436) and an unpublished map of the Pennyroyal Plain by Baskin and Baskin.

Geology

The xeric limestone prairies in Kentucky occur on Upper Silurian and Upper Mississippian calcareous substrates including limestone, dolomite and shale (Fig. 3). The sample sites in the Knobstone Escarpment and Knobs, Mammoth Cave Plateau and Pennyroyal Plain all occur on Upper Mississippian limestones, many of which also contain shale and/or dolomite. All nine xeric limestone prairies surveyed in the Knobstone Escarpment and Knobs are developed on

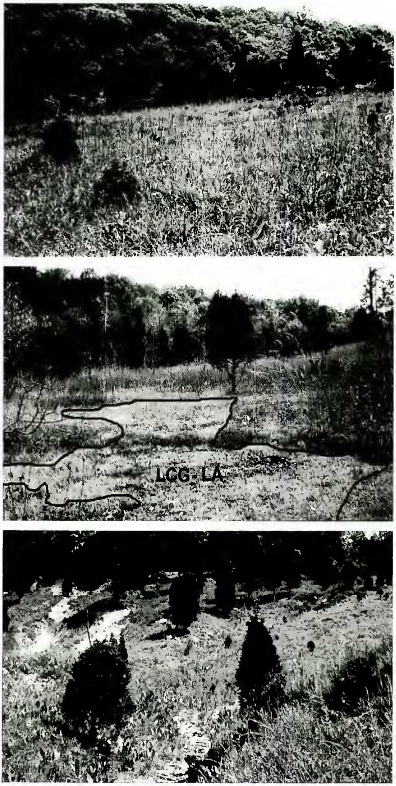

Fig. 1. Three xeric limestone prairies in the Interior Low Plateaus physiographic province in Kentucky. Top, Scudder Glade State Nature Preserve, Hardin County (photo by Carol Baskin, August 1980); middle, Pine Creek Barrens (The Nature Conservancy), Bullitt County (photo by Patrick Lawless, October 2003), XLP = xeric limestone prairie and LCG-LA = limestone cedar glade-like area, ; bottom, Crooked Creek Barrens State Nature Preserve, Lewis County (photo by Patrick Lawless, May 2002).

Fig. 2. Locations of sample sites in the Interior Low Plateaus physiographic province (map from Quarterman & Powell 1978). Subsections of Highland Rim Section: **H1**=Eastern Highland Rim, **H2**=Southern Highland Rim, **H3**=Western Highland Rim, **H4**=Southwestern Highland Rim, **H5**=Little Mountain, **H6**=Moulton Valley, **H7**=Pennyroyal Plain, **H8**=Elizabethtown [Plain], **H9**=Mitchell Plain, **H10**=Greensburg Upland, **H11**=Cumberland Enclave, **H12**=Norman Upland. Subsections of Central Basin Section: **C1**=Cumberland River Basin, **C2**=Harpeth River Basin, **C3**=Duck River Basin, **C4**=Elk River Basin. Subsections of Blue Grass Section: **B1**=Knobstone Escarpment and Knobs, **B2**=Northeastern Blue Grass, **B3**=Outer Blue Grass, **B4**=Eden Shale Belt, **B5**=Inner Blue Grass. Subsections of Shawnee Hills Section: **S1**=Mammoth Cave Plateau, **S2**=Marion [Area], **S3**=Illinois Ozarks, **S4**=Ohio River Hills & Lowlands, **S5**=Brush Creek Hills.

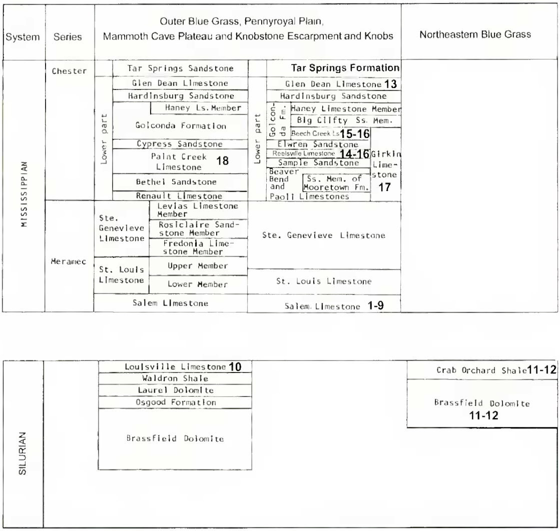

Fig. 3. Bedrock geology of xeric limestone prairies in the Outer Blue Grass (western and eastern), Pennyroyal Plain, Mammoth Cave Plateau, and Knobstone Escarpment and Knobs subsections of the Interior Low Plateaus physiographic province in Kentucky (from McDowell 1981). Numbers refer to site numbers in Table 1. The break between Upper Mississippian and Upper Silurian is for the Upper Devonian upon which xeric limestone prairies do not occur in Kentucky.

Salem Limestone, of the Meramecian Series (Keperfele 1966, 1967; Peterson 1966). Keperfele (1967) defines two main units within the Salem Limestone and describes the second unit in association with characteristic surface and vegetation features of xeric limestone prairies as follows: "an argillaceous limestone and shale" with a "surface marked by rounded gullied slopes barren except for scattered junipers."

All sample sites in the Mammoth Cave Plateau and Pennyroyal Plain occur on Upper Mississippian limestones of the Chesterian Series, many of which contain a significant shale component. Three of the four xeric limestone prairies in the Mammoth Cave Plateau (Lapland Road Barrens, Lapland Barrens and Knight's Barren) are on Reelsville Limestone, and two of the three sites (Lapland

Table 1. Site characteristics of 18 xeric limestone prairies surveyed in the Interior Low Plateaus physiographic province in Kentucky.

	Site	County	Physiographic Subsection of Interior Low Plateaus	Ownership	Soil Order(s)	Geologic Formation(s) (System)	Site Richness
1	Fort Knox Military Reservation 1	Hardin	Knobstone Esc. & Knobs	Dept of Defense	Alfisols, Mollisols	Salem Limestone (UM)	99
2	Fort Knox Military Reservation 2	Hardin	Knobstone Esc. & Knobs	Dept of Defense	Alfisols	Salem Limestone (UM)	126
3	Cedar Creek Farms	Hardin	Knobstone Esc. & Knobs	Private	Alfisols	Salem Limestone (UM)	123
4	Scudder Glade	Hardin	Knobstone Esc. & Knobs	KSNPC	Alfisols	Salem Limestone (UM)	125
5	Hardin Co. Cedar Glade	Hardin	Knobstone Esc. & Knobs	Private*	Alfisols	Salem Limestone (UM)	99
6	Muldraugh's Barren	Hardin	Knobstone Esc. & Knobs	Private	Alfisols	Salem Limestone (UM)	93
7	Mixed Grass Barrens	Larue	Knobstone Esc. & Knobs	Private	Alfisols	Salem Limestone (UM)	104
8	Spalding Glade	Larue	Knobstone Esc. & Knobs	KSNPC,Private **	Alfisols, Inceptisols	Salem Limestone (UM)	129
9	Thompson Creek Glade	Larue	Knobstone Esc. & Knobs	KSNPC	Alfisols	Salem Limestone (UM)	88
10	Pine Creek Barrens	Bullitt	Outer Blue Grass	TNC	Alfisols	Louisville Limestone (US)	151
11	Crooked Creek Barrens 1	Lewis	Outer Blue Grass	KSNPC	Alfisols	Upper Part of Crab Orchard (US), Lower Part of Crab Orchard (US) and Brassfield (US)	121
12	Crooked Creek Barrens 2	Lewis	Outer Blue Grass	KSNPC	Alfisols	Upper Part of Crab Orchard (US), Lower Part of Crab Orchard (US) and Brassfield (US)	114

TABLE 1. continued

	Site	County	Physiographic Subsection of Interior Low Plateaus	Ownership	Soil Order(s)	Geologic Formation(s) (System)	Site Richness
13	Grayson Co. Barren	Grayson	Mammoth Cave Plateau	Private	Alfisols	Glen Dean Limestone (UM)	117
14	Knight's Barren	Hardin	Mammoth Cave Plateau	Private*	Alfisols	Reelsville Limestone (UM)	95
15	Lapland Barrens	Meade	Mammoth Cave Plateau	Private*	Alfisols, Ultisols	Reelsville Limestone (UM), Beech Creek Limestone (UM)	108
16	Lapland Road Barrens	Meade	Mammoth Cave Plateau	Private	Alfisols	Reelsville Limestone (UM), Beech Creek Limestone (UM)	104
17	Logan Co. Glade	Logan	Pennyroyal Plain	KSNPC	Alfisols	Girkin Limestone (UM)	131
18	Logan Co. Barrens	Logan	Pennyroyal Plain	Private	Alfisols	Paint Creek Limestone (UM)	98

Ownership: KSNPC = Kentucky State Nature Preserves Commission **TNC** = The Nature Conservancy - Kentucky Chapter
*Under management agreement with The Nature Conservancy **Portion of site owned by KSNPC, remainder under private ownership
Geologic System: UM = Upper Mississippian, US = Upper Silurian

Road Barrens and Lapland Barrens) extend onto Beech Creek Limestone (Amos 1972; Moore 1965). The fourth site in the Mammoth Cave Plateau (Grayson County Barren) is restricted to Glen Dean Limestone (Gildersleeve 1978). The two sites in the Pennyroyal Plain are developed on Paint Creek Limestone (Logan County Barrens) and Girkin Limestone (Logan County Glade) (Miller 1968; Rainey 1965).

The single sample site in the western Outer Blue Grass (Pine Creek Barrens) is on Louisville Limestone (Upper Silurian), which is composed of dolomite and dolomitic limestone (Keperfele 1968). The two xeric limestone prairies in the eastern Outer Blue Grass (Crooked Creek Barrens 1 and 2) are formed on the Upper Part of the Crab Orchard formation, a variegated clay-shale, and the Lower Part of the Crab Orchard and Brassfield formations (undivided, Upper Silurian), which is composed of dolomite, dolomitic limestone and interbedded clay-shale (Peck & Pierce 1966).

Soils

Soils of xeric limestone prairies in Kentucky have mixed mineralogy, are fine-textured (Table 2), moderately to severely eroded and shallow to moderately deep (0 to ca. 1 m, Baskin et al. 1994). Forty-two percent of 376 soil depth measurements in the 18 sites were ≤ 10 cm, 76% ≤ 30 cm, 91% ≤ 60 cm, and only 6% > 1 m (Lawless, unpublished). Ten of the 13 soil series upon which xeric limestone prairies occur are Alfisols, and the remaining three series are Mollisols (Corydon), Ultisols (Gilpin) and Inceptisols (Garmon). Nine of the 18 sample sites are developed on the Caneyville series, a Typic Hapludalf (Fig. 4). In addition, many of the soil mapping units in xeric limestone prairies are rock outcrop complexes (e.g. Caneyville-Rock Outcrop Complex, Rock Outcrop-Corydon Complex and Rock Outcrop-Fredonia-Colbert Complex). All soil mapping units associated with sample sites in the Knobstone Escarpment and Knobs are members of the Garmon-Caneyville-Lenberg Soil Association, which in this region also includes the Corydon, Cumberland, Hagerstown and Vertrees series (Arms et al. 1979). Three of the four sites in the Mammoth Cave Plateau (Grayson County Barren, Lapland Road Barrens and Knight's Barrens) occur on the Caneyville series (Arms et al. 1979; Haagen 2001; Whitaker et al. 1972), and the fourth (Lapland Barrens) is the only site on the Rosine-Gilpin-Lenberg complex (Haagen 2001). Both sites in the Pennyroyal Plain (Logan County Barrens and Logan County Glade) are restricted to the Rock Outcrop-Fredonia-Colbert complex (Dye et al. 1975). The sample sites in the Outer Blue Grass occur on the Caneyville series (Pine Creek Barrens) (Whitaker & Waters 1986) and Beasley and Shrouts series (Crooked Creek Barrens 1 and 2) (USDA, NRCS, Soil survey of Lewis County, Kentucky. unpublished).

METHODS

In 2002 and 2003, each of 18 sites was visited a minimum of once per season in spring, summer and autumn. All vascular plant species were recorded and a

TABLE 2. Series, family, and great group of soils in the 18 xeric limestone prairies sampled in Kentucky. For site identification, see Table 1.

Soil Series	Family	Great Group	Site(s)
Beasley	Fine, mixed, active, mesic	Typic Hapludalfs	11, 12
Caneyville	Fine, mixed, active, mesic	Typic Hapludalfs	2, 3, 7, 8, 9, 10, 13, 14, 16
Colbert	Fine, smectitic, thermic	Vertic Hapludalfs	17, 18
Corydon	Clayey, mixed, superactive, mesic	Lithic Argiudolls	1, 5
Cumberland	Fine, mixed, semi-active, thermic	Rhodic Paleudalfs	6
Fredonia	Fine, mixed, active, mesic	Typic Hapludalfs	17, 18
Garmon	Fine-loamy, mixed, semi-active, mesic	Dystric Eutrudepts	8
Gilpin	Fine-loamy, mixed, active, mesic	Typic Hapludults	15
Hagerstown	Fine, mixed, semi-active, mesic	Typic Hapludalfs	3
Lenberg	Fine, mixed, semi-active, mesic	Ultic Hapludalfs	15
Rosine	Fine-silty, mixed, semi-active, mesic	Ultic Hapludalfs	15
Shrouts	Fine, mixed, mesic	Typic Hapludalfs	11, 12
Vertrees	Fine, mixed, semi-active mesic	Typic Paleudalfs	2,4, 6

species list prepared for each site. Gleason and Cronquist (1991) was used for field identification, and taxa not identified in the field were collected and determined in the University of Kentucky Herbarium (KY) with the aid of a stereomicroscope. Each taxon was assigned a presence value based on the percentage of sites in which it was recorded and placed in one of the following five presence classes (Cain & Castro 1959): 1 (1–20%), 2 (21–40%), 3 (41–60%), 4 (61–80%) and 5 (81–100%) . *Sporobolus vaginiflorus* was treated as a single taxon, since the two varieties found in this study are primarily distinguished by microscopic characters in both vegetative and reproductive states (FNEC 2003). Community coefficients (CC) were calculated for all possible pair-wise site comparisons using PC-ORD (McCune and Mefford 1999). Community coefficients [CC= 2W/(A+B)] are based on the number of taxa shared between sample sites (W) and the total number of taxa in site A and in site B. The life form (sensu Raunkiaer 1934) of each taxon was obtained from Gibson (1961), Hansen (1952), Ennis (1928) and Baskin and Baskin (1978) and the photosynthetic pathway from Baskin and Baskin (2003) and Waller and Lewis (1978). Life form and photosynthetic pathway also were determined for each of the 342 taxa reported by Chester et al. (1997) in the deep-soil barrens of the southwestern Pennyroyal Plain of Kentucky and Tennessee for comparisons with the floras of xeric limestone prairies in Kentucky and limestone cedar glades of the southeastern United States (Baskin & Baskin 1999). We reviewed the list of state endangered, threatened and special concern species published by the Kentucky State Nature Preserves Commission (2002) and noted all state-listed taxa occurring in the xeric limestone prairies of Kentucky.

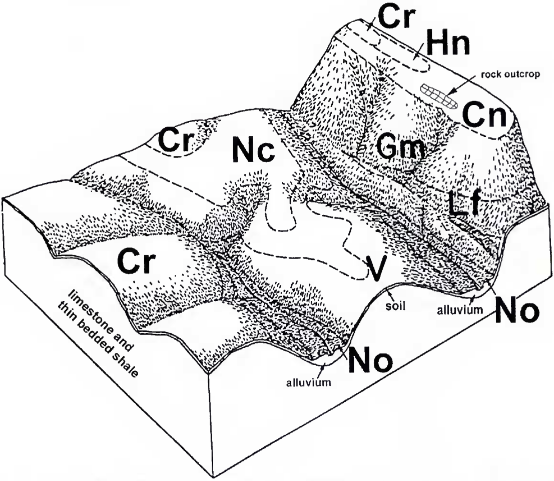

Fig. 4. A block diagram of the topography and soil series in the Knobs and Knobstone Escarpment section of the Interior Low Plateaus physiographic province in Hardin and Larue counties Kentucky. Soil series: **Cn**=Caneyville, **Cr**=Crider, **Gm**=Garmon, **Hn**=Hagerstown, **Lf**=Lenberg-Frondorf, **No**=Nolin-Newark-Melvin, **V**=Vertrees.

The geographic relationships of all taxa were determined by examining distribution maps obtained from Plants (USDA, NRCS 2004). Taxa in which Kentucky is in the central region of their current distribution were defined as intraneous, and those in which Kentucky is at the edge of their current distribution were defined as extraneous. When considering the geographic relationships of taxa in which Kentucky is near the edge of their range, the conservation status or rank and/or county distribution in the adjacent state was (were) considered, if available. If Kentucky is near the edge of the taxon's current distribution and the taxon is listed (endangered, threatened or special concern) in the adjacent state or only distributed in counties adjacent to the Kentucky border, the taxon was considered extraneous. The extraneous species were divided further into extraneous northern, southern, eastern and western groups in accordance with the position of Kentucky in relation to the center of distribution of the taxon of interest.

RESULTS

A total of 335 vascular plant taxa representing 333 species, 215 genera and 72 families were recorded in the 18 xeric limestone prairies surveyed (Appendix). The genera *Crataegus* and *Rubus* were each treated as a single taxon, because no flowering individuals were observed in either genus, both of which are characterized by intergradation of vegetative characters between/among species and high taxonomic diversity. Three hundred and fifteen (94.0%) of the 335 taxa are native to Kentucky, and the remaining 20 (6.0%) nonnative (Fig. 5). Asteraceae, Poaceae and Fabaceae had the highest richness values of all families, containing 70 (20.9%), 32 (9.6%) and 29 (8.7%) taxa, respectively. Genera with the largest number of taxa were *Symphyotrichum* (15), *Panicum* sensu lato (=*Panicum* + *Dichanthelium*) (10), *Carex* (7), *Solidago* (6) and *Hypericum* (6). The xeric limestone prairies in Kentucky support 24 state-listed taxa (9 endangered, 8 threatened and 7 special concern), including three species (*Delphinium carolinianum* ssp. *calciphilum*, *Leavenworthia exigua* var. *laciniata* and *Talinum calcaricum*) listed by Baskin and Baskin (1999) as cedar glade endemics. However, none of these state-listed taxa is federally listed, and none of the taxa recorded in this study is endemic to xeric limestone prairies in Kentucky. Furthermore, the three cedar glade endemics occur in areas of xeric limestone prairies that fit the description of limestone cedar glades when categorized at small spatial scales (Fig. 1).

The flora of xeric limestone prairies in Kentucky is composed primarily of native C_3 hemicryptophytes with broad geographical distributions encompassing Kentucky. Ninety-two and eight-tenths percent of the taxa are C_3 plants, and with the exception of *Manfreda virginica*, *Opuntia compressa* (CAM plants) and *Cuscuta cuspidata* (nonphotosynthetic), the remaining taxa are C_4 plants. The hemicryptophyte life form group contains more taxa (52.9% of native species) than all other life form groups combined (Fig. 5). Seventy-three and five-tenths percent of the native taxa in the xeric limestone prairie flora in Kentucky (230 taxa) is intraneous (Fig. 6), and taxa with southern geographic affinities (44 taxa, 14.1%) make up the largest extraneous component of the flora.

Although species richness values varied considerably across the 18 xeric limestone prairie sites surveyed, species composition among the sites was quite similar. Average site richness was 113 taxa (CV=13%) and ranged from 88 (Thompson Creek Glade) to 151 (Pine Creek Barrens) (Table 1). Calculation of community coefficients (CC's) for all possible pair-wise site comparisons determined that the majority of xeric limestone prairies surveyed form a single association or community type. Only 11 of the 153 CC's calculated were less than 0.50, the generally accepted association criterion (Barbour et al. 1999). Nine of the 11 CC's less than 0.50 included either site 1 or site 2 in Crooked Creek Barrens, and the CC resulting from comparison of Crooked Creek Barrens site 1 and site 2 is high

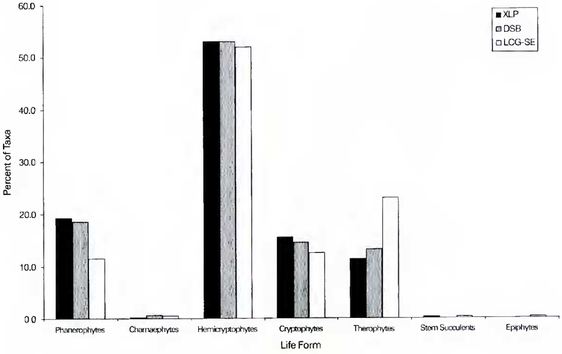

Fig. 5. Life form distribution of native species in the floras of xeric limestone prairies in Kentucky (XLP), deep-soil barrens of the southwestern Pennyroyal Plain (DSB) and limestone cedar glades of the southeastern U.S. (LCG-SE).

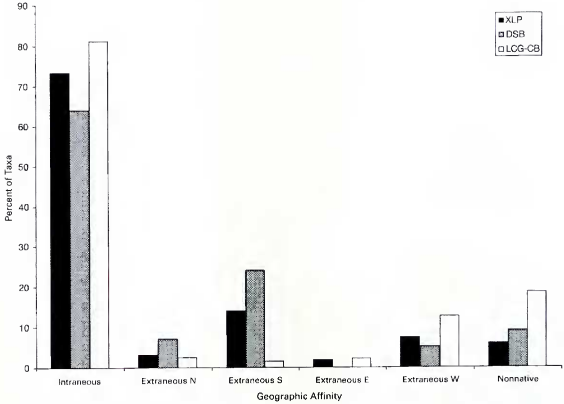

Fig. 6. Geographic affinities of the floras of xeric limestone prairies in Kentucky (XLP), deep-soil barrens of the southwestern Pennyroyal Plain (DSB) and cedar glades in the Central Basin of Tennessee (LCG-CB).

(0.71). These data suggest the two sites in Crooked Creek Barrens may belong to a second association or community type. Particularly noteworthy was the absence of *Echinacea simulata* and *Hypericum dolabriforme* in both Crooked Creek Barrens sites, since these taxa had high frequency values in the majority of the remaining sites (Lawless, unpublished). CC's ranged from 0.39 to 0.80, and the average CC (x=0.58) minus one standard deviation (s = 0.07) exceeds the generally accepted 0.50 association criterion.

As expected, the presence diagram for the xeric limestone prairie flora in Kentucky (Fig. 7) shows that the majority of species are in presence classes 1 and 2. However, the percentage of taxa in presence class four (15.3%) is similar to that in presence class two (18.0%), and thus class four approaches a second maximum (Oosting 1956). Only 13 taxa were present in all 18 sites, and all of them are native. Five of these 13 taxa are broadly distributed phanerophytes (*Cercis canadensis, Diospyros virginiana, Fraxinus americana, Juniperus virginiana* and *Rhamnus caroliniana*), two are dominant perennial (*Schizachyrium scoparium*) and annual (*Sporobolus vaginiflorus*) grass species in this community type (Baskin & Baskin 2000; Lawless, unpublished), and the remaining six species (*Euphorbia corollata, Helianthus hirsutus, Lobelia spicata, Physostegia virginiana, Ruellia humilis* and *Solidago nemoralis*) are relatively abundant forbs in the xeric limestone prairies in Kentucky (Lawless, unpublished).

DISCUSSION

The taxonomic distribution of the flora of xeric limestone prairies in Kentucky is very similar to that in the floras of cedar glades of the southeastern United States (Baskin & Baskin 1999) and of the deep-soil barrens of the Southwestern Pennyroyal Plain in Kentucky and Tennessee (Chester et al. 1999). However, the percentage of nonnative taxa in the xeric limestone prairie flora of Kentucky (6.0%) is considerably less than the percentages of nonnative taxa in the floras of the state of Kentucky (21.8%, Jones in press) of cedar glades of the Central Basin of Tennessee (18.7%, Baskin & Baskin 2003) and of southeastern United States (17.9%, Baskin & Baskin 1999) and of deep-soil barrens of the southwestern Pennyroyal Plain in Kentucky and Tennessee (9.1%, Chester et al. 1997) (Fig. 6). Furthermore, the vast majority of nonnative species in the xeric limestone prairie flora in Kentucky have low presence values. Nine of 20 taxa were present in only one site, and 18 occurred in four sites or less. The low percentage of nonnative taxa in the flora of xeric limestone prairies in Kentucky may be due to erosion of the organic horizon in these sites, which presumably has reduced nutrient availability in the surface layer. This reduction in surface layer nutrient availability may significantly decrease survivorship of nonnative seedlings, as these taxa typically are adapted to nutrient-rich sites (Grime 1974).

Asteraceae and Poaceae have the highest richness values of all families in the floras of xeric limestone prairies in Kentucky, cedar glades of the south-

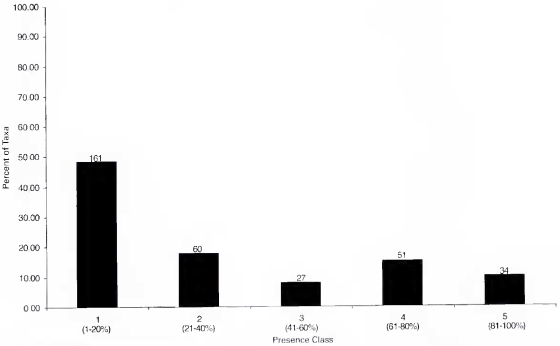

Fig. 7. Percent of taxa in each of five presence classes in 18 xeric limestone prairies surveyed in the Interior Low Plateaus physiographic province in Kentucky. Presence classes are as follows: 1=1–20%, 2=21–40%, 3=41–60%, 4=61–80% and 5=81–100%. Number of taxa in presence class above each bar.

eastern United States and deep-soil barrens of the southwestern Pennyroyal Plain, collectively accounting for 30.4%, 20.9% and 33.3%, respectively, of taxa in these floras. The Fabaceae ranks third in species richness in the floras of xeric limestone prairies in Kentucky and deep-soil barrens, whereas species richness in the Cyperaceae exceeds that in the Fabaceae in the flora of cedar glades of the southeastern United States. The flora of cedar glades also is distinguished by 19 endemic and two near-endemic taxa. The genus *Panicum* sensu lato contains the largest number of taxa in the floras of cedar glades (16 taxa) and deep-soil barrens (10 taxa). The flora of xeric limestone prairies in Kentucky also is rich in *Panicum* species sensu lato (10 taxa); however, *Symphyotrichum* had the highest richness of all genera (15 taxa).

The geographic affinities, photosynthetic pathway and life form distributions among the floras of xeric limestone prairies in Kentucky, limestone cedar glades and deep-soil barrens are similar. However, the flora of limestone cedar glades differs from that of the other two community types in three important aspects. The floras of xeric limestone prairies and deep-soil barrens contain a strong extraneous southern component (14.1 % and 24.0% of floras, respectively). In contrast, taxa with western or northwestern geographical affinities make up the largest percentage of extraneous taxa (12.6% of flora) in the limestone cedar glade flora (Baskin & Baskin 1999). The phanerophyte life form group contains a considerably smaller percentage of native taxa in the flora of limestone cedar glades (11.5%) in comparison with the floras of xeric limestone prairies in Kentucky (19.4%) and deep-soil barrens (18.6%) (Fig. 5). The flora of limestone cedar glades also is distinguished by a relatively high percentage of native therophytes (23.0%), many of which are winter annuals. The cedar glade flora contains eight winter annuals in the genus *Leavenworthia* alone, which partially accounts for the richness of the Brassicaceae (17 taxa) in this community type and for the near endemic status of the genus *Leavenworthia* in the southeastern United States (Baskin & Baskin 2003; Estill & Cruzan 1999). Conversely, the xeric limestone prairie flora in Kentucky contains only two native winter annuals, *Leavenworthia uniflora* and *Leavenworthia exigua* var. *laciniata*, both of which occur in cedar glade-like areas of the perennial grassland matrix (Fig. 1), and this life cycle type is absent in the deep-soil barrens flora.

The winter annual life cycle is an adaptive phenological strategy in limestone cedar glades. It assures completion of the life cycle prior to summer-dry conditions, which winter annuals pass in the drought-tolerant seed stage (Baskin & Baskin 1985). The paucity of winter annuals in the floras of xeric limestone prairies in Kentucky and deep-soil barrens of the southwestern Pennyroyal Plain suggest the edaphic conditions in these habitats are considerably less severe, and/or these communities have not existed for a sufficient period to allow for evolution of the annual life cycle in a comparable proportion of resident taxa.

Although the xeric limestone prairies surveyed support no endemic or federally listed taxa, this community type is the primary habitat in Kentucky for almost all of the 24 state-listed species recorded in the present study. Therefore, preservation of these species in Kentucky is dependent upon conservation of the xeric limestone prairie community type. Presently, nine of the 18 sites surveyed are owned by conservation organizations (Kentucky State Nature Preserves Commission and The Nature Conservancy) or by the federal government (Fort Knox Military Reservation). Three of the remaining nine sites (Hardin County Cedar Glade, Knight's Barrens and Lapland Barrens) are under management agreement with The Nature Conservancy, and the Logan County NRCS office is currently in the process of purchasing Logan County Barrens, one of the two sites surveyed in the Pennyroyal Plain. The most significant threat to xeric limestone prairie conservation is all terrain vehicle (ATV) usage, which damages or destroys vegetation, thus promoting further erosion of denuded soils.

Baskin et al. (1994) proposed the following sequence of events for the origin of xeric limestone prairies in Kentucky: clearing of marginal agricultural lands by European settlers → cultivation and/or grazing → significant erosion of the topsoil → abandonment → colonization of these degraded areas by the xeric limestone prairie flora → succession to hardwood forest in the absence of disturbance or maintenance of xeric limestone prairie with periodic management (i.e. disclimax). Forest succession is retarded by the highly eroded soils of these abandoned hillsides and by large heat loads (sensu McCune and Grace 2002) associated with the moderate to steep slopes with south to west aspects. However, succession to hardwood forest eventually occurs in the absence of management, which typically consists of mechanical removal of large trees, particularly *Juniperus virginiana*, and periodic prescribed fire (2-5 year burning interval, David Skinner, KSNPC Eastern Preserve Manager, personal communication).

The species composition of this community type is relatively consistent despite 1) their relatively recent origin, 2) the rarity of xeric limestone prairies at the landscape scale and 3) the small area occupied by these communities in the matrix of deciduous forests and agricultural lands. The richness of Asteraceae and Poaceae in the xeric limestone prairie flora of Kentucky is primarily responsible for the relatively high community coefficients ($x = 0.58$) observed in this study, since both of these families are characterized by large regional species pools and high proportions of wind-dispersed taxa. Furthermore, we have observed many taxa in the xeric limestone prairie flora (e.g. *Schizachyrium scoparium*, *Panicum flexile*, *Liatris squarrulosa*, *Ratibida pinnata*, *Croton monanthogynous*, *Hypericum dolabriforme*, etc.) in open forests with shallow rocky soils, on rock ledges and on rocky stream banks. These habitats, in addition to deep-soil barrens and limestone cedar glades, are the likely sources of the xeric limestone prairie flora in Kentucky, since they existed prior to European settlement.

CONCLUSIONS

Xeric limestone prairies are broadly distributed throughout the Interior Low Plateaus physiographic province in Kentucky and are most frequent in the Knobstone Escarpment and Knobs, where they primarily occur on eroded Alfisols derived from the Upper Mississippian Salem Limestone. The flora is rich in species of Asteraceae and Poaceae and contains 24 state-listed species, many of which are restricted to xeric limestone prairies in this part of their geographic range. Community coefficients suggest that all sample sites except those in the eastern Outer Blue Grass (Crooked Creek Barrens 1 and 2) belong to a single community type. Xeric limestone prairies are relatively well protected in Kentucky; the majority of sites are owned and/or managed by conservation organizations and the federal government.

The majority of taxa in the floras of xeric limestone prairies in Kentucky, limestone cedar glades of the southeastern United States and deep-soil barrens of the southwestern Pennyroyal Plain in Kentucky and Tennessee are intraneous C_3 hemicryptophytes. The very low percentage (6.0) of nonnative species in the xeric limestone prairie flora of Kentucky is noteworthy. Among xeric limestone prairies, limestone cedar glades and deep-soil barrens, the flora of limestone cedar glades is particularly unique due to 1) 21 endemic/near endemic taxa, 2) relatively high percentage of therophytes and 3) an extraneous component with strong western and northwestern affinities (Baskin & Baskin 1999).

In contrast, the floras of xeric limestone prairies in Kentucky and deep-soil barrens of the southwestern Pennyroyal Plain 1) contain no endemic taxa, 2) have higher percentages of phanerophyte taxa and 3) have an extraneous component with strong southern geographic affinities.

APPENDIX

Taxonomy is in accordance with USDA, NRCS (2004), with the exception of *Elymus glabriflorus* var. *australis*, which is based on the treatment by Campbell (1995). The name and authority for each taxon is followed, in parentheses, by the photosynthetic pathway (C3, C4 or CAM), life form (Ph=phanerophyte, Ch=chamaephyte, H=hemicryptophyte, Cr=cryptophyte and Th=therophyte; HP=holoparasite), geographic affinity (I=intraneous, EN=extraneous northern, ES=extraneous southern, EE=extraneous eastern, EW=extraneous western and X=introduced) and conservation status in the state of Kentucky (E=endangered, T=threatened and S=special concern) (KSNPC 2002) in bold-faced type. Number in bold-faced type following the final parenthesis refers to number of sites in which species was recorded.

DIVISION PTERIDOPHYTA, FERNS AND FERN ALLIES

ADIANTACEAE
Pellaea atropurpurea (L.) Link (C3, H, I) **5**

ASPLENIACEAE
Asplenium platyneuron (L.) B.S.P. (C3, H, I) **3**

OPHIOGLOSSACEAE
Ophioglossum englemannii Prantl (C3, Cr, ES) **2**

DIVISION PINOPHYTA, CONIFERS

CUPRESSACEAE
Juniperus virginiana L. (C3, Ph, I) **18**

PINACEAE
Pinus virginiana Mill. (C3, Ph, I) **5**

DIVISION MAGNOLIOPHYTA, FLOWERING PLANTS

CLASS MAGNOLIOPSIDA (DICOTS)

ACANTHACEAE
Ruellia humilis Nutt. (C3, H, I) **18**

ACERACEAE
Acer rubrum L. (C3, Ph, I) **9**
Acer saccharum Marshall (C3, Ph, I) **11**

ANACARDIACEAE
Rhus aromatica Aiton (C3, Ph, I) **7**
Rhus copallinum L. (C3, Ph, I) **12**
Rhus glabra L. (C3, Ph, I) **2**
Toxicodendron radicans (L.) Kuntze (C3, Ph, I) **9**

APIACEAE
Daucus carota L. (C3, H, X) **1**
Eryngium yuccifolium Michx. (C3, Cr, ES) **10**
Oxypolis rigidior (L.) Raf. (C3, Cr, I) **1**
Sanicula canadensis L. (C3, Cr, I) **7**
Thaspium barbinode (Michx.) Nutt. (C3, Cr, I) **12**
Zizia aptera (Gray) Fernald (C3, H, I) **10**
Zizia aurea (L.) W.D.J. Koch (C3, Cr, I) **6**

APOCYNACEAE
Apocynum cannabinum L. (C3, H, I) **14**

ARISTOLOCHIACEAE
Aristolochia serpentaria L. (C3, H, I) **12**

ASCLEPIADACEAE
Asclepias tuberosa L. (C3, H, I) **1**
Asclepias verticillata L. (C3, H, I) **12**
Asclepias viridiflora L. (C3, H, I) **17**
Matelea obliqua (Jacq.) Woodson (C3, I, ES) **4**

ASTERACEAE
Achillea millefolium L. (C3, H, I) **1**
Ageratina altissima (L.) King & H.E. Robins. (C3, H, I) **1**
Ambrosia artemisiifolia L. (C3, Th, I) **10**
Ambrosia trifida L. (C3, Th, I) **2**

Arnoglossum atriplicifolium (L.) H.E. Robins. (C3, H, I) **2**
Antennaria plantaginifolia (L.) Richards (C3, Ch, I) **2**
Brickellia eupatoriodies (L.) Shinners (C3, H, I) **16**
Centaurea biebersteinii DC. (C3, H, X) **1**
Cirsium discolor (Muhl. ex Willd.) Spreng. (C3, H, I) **6**
Conoclinium coelestinum (L.) DC. (C3, H, ES) **3**
Conyza canadensis (L.) Cronquist (C3, Th, I) **8**
Coreopsis tripteris L. (C3, H, EN) **14**
Echinacea simulata McGregor (C3, H, EW) **14**
Erigeron strigosus Muhl. ex Willd. (C3, H, I) **6**
Eupatorium altissimum L. (C3, H, ES) **13**
Eupatorium hyssopifolium L. (C3, H, ES) **1**
Eupatorium perfoliatum L. (C3, H, I) **2**
Euthamia graminifolia (L.) Nutt. (C3, H, EN) **4**
Helenium autumnale L. (C3, H, I) **7**
Helianthus divaricatus L. (C3, Cr, I) **4**
Helianthus hirsutus Raf. (C3, Cr, I) **18**
Helianthus microcephalus Torr. & Gray (C3, H, ES) **5**
Helianthus mollis Lam. (C3, Cr, I) **4**
Helianthus occidentalis Riddell (C3, Cr, I) **3**
Heliopsis helianthoides (L.) Sweet (C3, Cr, I) **3**
Leucanthemum vulgare Lam. (C3, H, X) **4**
Liatris aspera Michx. (C3, Cr, EW) **10**
Liatris cylindracea Michx. (C3, Cr, EW, **T**) **2**
Liatris spicata (L.) Willd. (C3, Cr, I) **8**
Liatris squarrosa (L.) Michx. var. *squarrosa* (C3, Cr, ES) **15**
Liatris squarrulosa Michx. (C3, Cr, ES) **3**
Lonactis linariifolius (L.) Greene (C3, H, I) **4**
Oligoneuron rigidum (L.) Small var. *glabratum* (E.L. Braun) Nesom (C3, H, EW) **11**
Packera anonyma (Wood) W.A. Weber & A. Löve (C3, H, ES) **5**
Parthenium integrifolium L. (C3, H, I) **12**
Prenanthes aspera Michx. (C3, H, EW, **E**) **1**
Ratibida pinnata (Vent.) Barnhart (C3, H, EW) **10**
Rudbeckia fulgida Aiton (C3, H, I) **12**
Rudbeckia hirta L. (C3, H, I) **1**
Senecio glabellus Poir. (C3, Th, ES) **1**
Sericocarpus asteroides (L.) B.S.P. (C3, H, EE) **1**
Silphium laciniatum L. (C3, H, EW, **E**) **1**
Silphium pinnatifidum Elliott (C3, H, ES, **S**) **3**
Silphium terebinthinaceum Jacq. (C3, H, EW) **5**
Silphium trifoliatum var. *trifoliatum* L. (C3, H, EE) **17**
Solidago bicolor L. (C3, H, I) **1**
Solidago canadensis L. (C3, H, I) **6**
Solidago juncea Aiton (C3, H, I) **1**
Solidago nemoralis Aiton (C3, H, I) **18**
Solidago speciosa Nutt. var. *erecta* (Pursh) MacMill. (C3, H, ES) **3**
Solidago sphacelata Raf. (C3, H, ES) **1**
Solidago ulmifolia Muhl. ex Willd. var. *ulmifolia* (C3, H, I) **11**
Symphyotrichum cordifolium (L.) Nesom (C3, H, I) **2**
Symphyotrichum dumosum (L.) Nesom (C3, H, I) **1**
Symphyotrichum laeve (L.) A. & D. Löve var. *concinum* (Willd.) Nesom (C3, H, I) **2**
Symphyotrichum laeve (L.) A. & D. Löve var. *laeve* (C3, H, I) **12**
Symphyotrichum laterifolium (L.) A. & D. Löve (C3, H, I) **1**
Symphyotrichum novae-angliae (L.) Nesom (C3, H, I) **4**
Symphyotrichum oblongifolium (Nutt.) Nesom (C3, H, I) **2**
Symphyotrichum oolentangiense (Riddell) Nesom (C3, H, EW) **2**
Symphyotrichum patens (Aiton) Nesom var. *patens* (C3, H, I) **12**
Symphyotrichum pilosum (Willd.) Nesom var. *pilosum* (C3, H, I) **4**
Symphyotrichum pilosum (Willd.) Nesom var. *pringlei* (Gray) Nesom (C3, H, EN) **12**
Symphyotrichum sericeum (Vent.) Nesom (C3, H, ES, **S**) **6**
Symphyotrichum shortii (Lindl.) Nesom (C3, H, I) **1**
Symphyotrichum undulatum (L.) Nesom (C3, H, EE) **1**
Symphyotrichum urophyllum (Lindl.) Nesom (C3, H, I) **12**
Taraxacum officinale G.H.Weber ex Wiggers (C3, H, X) **2**
Verbesina virginica L. (C3, H, I) **4**
Vernonia gigantea (Walter) Trel. (C3, H, I) **4**

BETULACEAE
Corylus americana Walter (C3, Ph, EN) **2**
Ostrya virginiana (Mill.) Koch (C3, Ph, I) **16**

BIGNONIACEAE
Bignonia capreolata L. (C3, Ph, I) **1**
Campsis radicans (L.) Seem. ex Bureau (C3, Ph, ES) **1**

BORAGINACEAE
Heliotropium tenellum (Nutt.) Torr. (C3, Th, ES) **9**

Lithospermum canescens (Michx.) Lehm. (C3, H, I) **16**

BRASSICACEAE

Arabis laevigata (Muhl. ex Willd.) Poir. var. *laevigata* (C3, H, I) **1**
Cardamine hirsuta L. (C3, Th, X) **1**
Draba verna L. (C3, Th, X) **1**
Leavenworthia exigua Rollins var. *laciniata* Rollins (C3, Th, ES, **T**) **1**
Leavenworthia uniflora (Michx.) Britton (C3, H, I) **2**

CACTACEAE

Opuntia humifusa (Raf.) Raf. (CAM, S, ES) **3**

CAMPANULACEAE

Lobelia spicata Lam. (C3, H, I) **18**

CAPRIFOLIACEAE

Lonicera japonica Thunb. (C3, Ph, X) **4**
Symphoricarpos orbiculatus Moench (C3, Ph, I) **6**
Viburnum prunifolium L. (C3, Ph, I) **4**
Viburnum rufidulum Raf. (C3, Ph, ES) **6**

CARYOPHYLLACEAE

Dianthus armeria L. (C3, Th, X) **1**
Minuartia patula (Michx.) Mattf. (C3, Th, I) **1**

CELASTRACEAE

Celastrus scandens L. (C3, Ph, I) **7**

CLUSIACEAE

Hypericum denticulatum Ellis (C3, H, EE) **2**
Hypericum dolabriforme Vent. (C3, H, ES) **14**
Hypericum hypericoides (L.) Crantz (C3, H, ES) **2**
Hypericum prolificum L. (C3, Ph, I) **6**
Hypericum punctatum L. (C3, H, I) **5**
Hypericum sphaerocarpum L. (C3, H, EW) **2**

CONVOLVULACEAE

Calystegia spithamaea (L.) Pursh (C3, H, I) **1**
Ipomoea pandurata (L.) G.F. Mey. (C3, Cr, I) **12**

CORNACEAE

Cornus drummondii C. A. Mey. (C3, Ph, EW) **4**
Cornus florida L. (C3, Ph, I) **10**

CRASSULACEAE

Sedum ternatum Michx. (C3, Th, I) **2**

CUSCUTACEAE

Cuscuta cuspidata Engelm. (HP, Th, EW) **1**

EBENACEAE

Diospyros virginiana L. (C3, Ph, I) **18**

ERICACEAE

Vaccinium arboreum Marshall (C3, Ph, ES) **4**
Vaccinium pallidum Aiton (C3, Ph, I) **1**

EUPHORBIACEAE

Acalypha gracilens Gray (C3, Th, I) **6**
Acalypha virginica L. (C3, Th, I) **1**
Chamaesyce nutans (Lag.) Small (C3, Th, I) **8**
Croton capitatus Michx. (C3, Th, I) **12**
Croton monanthogynous Michx. (C3, Th, ES) **7**
Euphorbia corollata L. (C3, Cr, I) **18**
Euphorbia dentata Michx. (C3, Th, I) **3**

FABACEAE

Cercis canadensis L. (C3, Ph, I) **18**
Chamaecrista fasciculata (Michx.) Greene var. *fasciculata* (C3, Th, I) **11**
Coronilla varia L. (C3, Th, X) **1**
Dalea candida Michx. ex Willd. var. *candida* (C3, H, EW) **1**
Dalea purpurea Vent. var. *purpurea* (C3, H, EW, **S**) **5**
Desmodium canescens (L.) DC. (C3, H, I) **2**
Desmodium ciliare (Muhl. ex Willd.) DC. (C3, H, I) **12**
Desmodium glabellum (Michx.) DC (C3, H, ES) **4**
Desmodium paniculatum (L.) DC. var. *paniculatum* (C3, H, I) **1**
Desmodium rotundifolium DC. (C3, H, I) **1**
Desmodium sessilifolium (Torr.) Torr. & Gray (C3, H, I) **1**
Desmanthus illinoensis (Michx.) MacMill. ex B.L. Robins. & Fern. (C3, Ph, EW) **1**
Galactia volubilis (L.) Britton (C3, H, I) **15**
Gleditsia triacanthos L. (C3, Ph, I) **3**
Lespedeza capitata Michx. (C3, H, I, **S**) **3**
Lespedeza cuneata (Dum.Cours.) G. Don (C3, H, X) **2**
Lespedeza procumbens L. (C3, H, I) **3**
Lespedeza repens (L.) W. Bartram (C3, H, I) **1**
Lespedeza violacea (L.) Pers. (C3, H, I) **2**
Lespedeza virginica (L.) Britton (C3, H, I) **16**
Melilotus alba Medikus (C3, H, X) **8**
Orbexilum pedunculatum (Mill.) Rydb. var. *psoralioides* (Walt.) Isley (C3, Cr, ES) **1**
Robinia pseudoacacia L. (C3, Ph, I) **2**
Senna marilandica (L.) Link (C3, H, I) **4**
Strophostyles umbellata (Muhl. ex Willd.) Britton (C3, Cr, ES) **3**
Stylosanthes biflora (L.) B.S.P. (C3, H, ES) **6**
Tephrosia virginiana (L.) Pers. (C3, H, I) **8**

Trifolium repens L. (C3, H, X) **1**
Vicia villosa Roth (C3, H, X) 2

FAGACEAE
Fagus grandifolia Ehrh. (C3, Ph, I) **5**
Quercus alba L. (C3, Ph, I) **2**
Quercus imbricaria Michx. (C3, Ph, I) **3**
Quercus marilandica Muenchh. (C3, Ph, ES) **13**
Quercus muehlenbergii Engelm. (C3, Ph, I) **13**
Quercus prinus L. (C3, Ph, I) **1**
Quercus rubra L. (C3, Ph, I) **10**
Quercus stellata Wangenh. (C3, Ph, I) **15**
Quercus velutina Lam. (C3, Ph, I) **6**

GENTIANACEAE
Frasera caroliniensis Walters (C3, H, I) **2**
Gentiana flavida Muhl. ex Nutt. (C3, H, I, **E**) **1**
Gentianella quinquefolia (L.) Small ssp. *occidentalis* (Gray) J. Gillett (C3, H, I) **9**
Sabatia angularis (L.) Pursh (C3, H, I) **15**

JUGLANDACEAE
Carya alba (L.) Nutt. ex Ellis (C3, Ph, I) **3**
Carya tomentosa Nutt. (C3, Ph, I) **3**
Juglans nigra L. (C3, Ph, I) **13**

LAMIACEAE
Blephilia ciliata (L.) Benth. (C3, H, I) **13**
Isanthus brachiatus B.S.P. (C3, Th, I) **13**
Lycopus americanus Muhl. ex W. Bartram (C3, H, I) **1**
Monarda fistulosa L. (C3, H, I) **13**
Physostegia virginiana (L.) Benth. (C3, H, I) **18**
Prunella vulgaris L. var. *lanceolata* (Barton) Fernald (C3, H, I) **16**
Pycnanthemum pycnanthemoides (Leavenw.) Fernald (C3, H, ES) **2**
Pycnanthemum tenuifolium Schrad. (C3, H, I) **11**
Salvia lyrata L. (C3, H, I) **5**
Scutellaria elliptica Muhl. (C3, H, I) **3**
Scutellaria parvula Michx. var. *australis* Fassett (C3, Cr, I) **8**
Scutellaria parvula Michx. var. *missouriensis* (Torr.) Goodman & Lawson (C3, Cr, I) **2**
Trichostema dichotomum L. (C3, Th, I) **1**

LAURACEAE
Sassafrass albidum (Nutt.) Nees (C3, Ph, I) **11**

LINACEAE
Linum medium (Planch.) Britton (C3, H, I) **1**
Linum sulcatum Riddell (C3, Th, EW) **16**
Linum virginianum L. (C3, H, I) **2**

LYTHRACEAE
Cuphea viscosissima Jacq. (C3, Th, ES) **2**

MAGNOLIACEAE
Liriodendron tulipifera L. (C3, Ph, I) **6**

MALVACEAE
Malvastrum hispidum (Pursh) Hochr. (C3, Th, EW, **T**) **1**

OLEACEAE
Forestiera ligustrina (Michx.) Poir. (C3, Ph, ES, **T**) **1**
Fraxinus americana L. (C3, Ph, I) **18**
Ligustrum sinense Lour. (C3, Ph, X) **1**

ONAGRACEAE
Gaura biennis L. (C3, H, EE) **4**
Gaura filipes Spach (C3, H, ES) **13**
Oenothera biennis L. (C3, H, I) **1**

OXALIDACEAE
Oxalis stricta L. (C3, H, I) **1**
Oxalis violacea L. (C3, H, I) **1**

PAPAVERACEAE
Sanguinaria canadensis L. (C3, Cr, I) **1**

PASSIFLORACEAE
Passiflora lutea L. (C3, H, I) **2**

PLANTAGINACEAE
Plantago aristata Michx. (C3, Th, I) **1**
Plantago patagonica Jacq. (C3, Th, X) **1**
Plantago virginica L. (C3, Th, I) **4**

PLATANACEAE
Platanus occidentalis L. (C3, Ph, I) **1**

POLEMONIACEAE
Phlox pilosa L. ssp. *pilosa* (C3, H, I) **8**

POLYGALACEAE
Polygala verticillata L. (C3, Th, I) **13**

PORTULACACEAE
Talinum calcaricum Ware (C3, H, ES, **E**) **1**

PRIMULACEAE
Anagallis arvensis L. (C3, Th, X) **3**
Dodecatheon meadia L. (C3, H, I) **1**
Lysimachia lanceolata Walter (C3, H, I) **6**

RANUNCULACEAE
Anemone virginiana L. (C3, H, I) **13**
Clematis pitcheri Torr. & Gray var. *pitcheri* (C3, Ph, EW) **1**
Delphinium carolinianum Walter ssp. *calciphilum* Warnock (C3, H, ES, **T**) **1**

Thalictrum revolutum DC. (C3, H, I) **3**
Thalictrum thalictroides (L.) Eames & Boivin (C3, Cr, I) **2**

RHAMNACEAE
Ceanothus americanus L. (C3, Ph, I) **3**
Rhamnus caroliniana Walter (C3, Ph, ES) **18**

ROSACEAE
Agrimonia rostellata Wallr. (C3, H, I) **6**
Amelanchier arborea (Michx. f.) Fernald (C3, Ph, I) **6**
Crataegus L. [sp(p).] (C3, Ph) **5**
Fragaria virginiana Duchesne (C3, H, I) **5**
Porteranthus stipulatus (Muhl. ex Willd.) Britton (C3, H, I) **1**
Potentilla simplex Michx. (C3, H, I) **17**
Prunus americana Marshall (C3, Ph, I) **1**
Prunus serotina Ehrh. (C3, Ph, I) **7**
Rosa carolina L. (C3, Ph, I) **16**
Rosa multiflora Thunb. (C3, Ph, X) **4**
Rubus L. [sp(p).] (C3, Ph) **9**

RUBIACEAE
Diodia teres Walter (C3, Th, I) **4**
Galium circaezans Michx. (C3, H, I) **11**
Galium pilosum Aiton (C3, H, I) **7**
Galium triflorum Michx. (C3, H, I) **1**
Hedyotis nigricans (Lam.) Fosberg (C3, Th, EW) **11**
Houstonia canadensis Willd. ex Roemer & J.A. Schultes (C3, H, EN) **13**

SALICACEAE
Salix humilis Marshall (C3, Ph, I) **1**

SANTALACEAE
Comandra umbellata (L.) Nutt. (C3, Cr, I) **1**

SCROPHULARIACEAE
Agalinis auriculata (Michx.) Blake (C3, Th, EW, **E**) **1**
Agalinis gattingeri (Small) Small (C3, Th, EW) **4**
Agalinis tenuifolia (Vahl) Raf. (C3, Th, I) **9**
Aureolaria flava (L.) Farw. (C3, Cr, I) **2**
Buchnera americana L. (C3, H, ES) **1**
Castilleja coccinea (L.) Spreng. (C3, Th, I, **E**) **3**
Pedicularis canadensis L. (C3, H, I) **3**
Penstemon digitalis Nutt. ex Sims (C3, H, I) **1**
Penstemon hirsutus (L.) Willd. (C3, H, I) **2**

SIMAROUBACEAE
Ailanthus altissima (Mill.) Swingle (C3, Ph, X) **1**

SOLANACEAE
Physalis virginiana Mill. (C3, Cr, ES) **12**
Solanum carolinense L. (C3, Cr, I) **1**

ULMACEAE
Celtis occidentalis L. (C3, Ph, I) **1**
Celtis tenuifolia Nutt. (C3, Ph, I) **17**
Ulmus alata Michx. (C3, Ph, ES) **6**
Ulmus rubra Muhl. (C3, Ph, I) **3**

VERBENACEAE
Phryma leptostachya L. (C3, H, I) **1**
Verbena simplex Lehm. (C3, H, I) **6**

VIOLACEAE
Hybanthus concolor (T. Forst.) Spreng. (C3, H, I) **3**
Viola egglestonii Brainerd (C3, H, ES, **S**) **9**
Viola palmata L. (C3, H, I) **7**
Viola pedata L. (C3, H, I) **12**
Viola sagittata Aiton (C3, H, I) **2**

VITACEAE
Parthenocissus quinquefolia (L.) Planch. (C3, Ph, I) **9**
Vitis aestivalis Michx. (C3, Ph, I) **11**

DIVISION MAGNOLIOPHYTA, FLOWERING PLANTS CLASS LILIOPSIDA (MONOCOTS)

AGAVACEAE
Manfreda virginica (L.) Salisb. ex Rose (CAM, H, ES) **16**

CYPERACEAE
Carex complanata Torr. & Hook. (C3, Cr, I) **9**
Carex crawei Dewey (C3, Cr, I, **S**) **14**
Carex glaucodea Tuckerman ex Olney (C3, H, I) **8**
Carex juniperorum Catling, Reznicek & Crins (C3, H, EN, **E**) **2**
Carex meadii Dewey (C3, Cr, I) **16**
Carex pensylvanica Lam. (C3, Cr, I) **2**
Carex umbellata Schkuhr ex Willd. (C3, H, I) **12**
Eleocharis compressa Sullivant (C3, Cr, ES) **3**
Eleocharis tenuis (Willd.) J.A. Schultes (C3, Cr, I) **3**
Fimbristylis puberula (Michx.) Vahl var. *puberula* (C4, Cr, I, **T**)
Scirpus pendulus Muhl. (C3, H, I) **8**
Scleria oligantha Michx. (C3, Cr, I) **13**
Scleria pauciflora Muhl. (C3, Cr, I) **2**

DIOSCOREACEAE
Dioscorea quaternata J.F. Gmel (C3, Ph, I) **2**

IRIDACEAE
Hypoxis hirsuta (L.) Coville (C3, Cr, I) **2**

Iris cristata Aiton (C3, Cr, I) **1**
Sisyrinchium albidum Raf. (C3, H, I) **13**

LILIACEAE

Allium cernuum Roth (C3, Cr, EN) **8**
Maianthemum stellatum (L.) Link (C3, Cr, I, **E**) **1**
Nothoscordum bivalve (L.) Britton (C3, Cr, I) **1**
Polygonatum biflorum (Walter) Elliott (C3, Cr, I) **10**
Uvularia perfoliata L. (C3, Cr, I) **1**

ORCHIDACEAE

Cypripedium candidum Muhl. ex Willd. (C3, Cr, EN, **E**) **2**
Cypripedium pubescens Willd. var. *pubescens* (C3, Cr, I) **2**
Spiranthes lacera (Raf.) Raf. var. *gracilis* (Bigelow) Leur (C3, H, I) **4**
Spiranthes magnicamporum Sheviak (C3, H, EW, **T**) **9**
Tipularia discolor (Pursh) Nutt. (C3, Cr, I) **1**

POACEAE

Andropogon gerardii Vitman (C4, H, I) **17**
Aristida longispica Poir. (C4, Th, I) **1**
Aristida oligantha Michx. (C4, Th, I) **2**
Aristida purpurascens Poir. var. *purpurascens* (C4, H, I) **13**
Bouteloua curtipendula (Michx.) Torr. (C4, H, I, **S**) **3**
Brachyeletrum erectum (Schreb. ex Spreng.) Beauvis. (C3, H, I) **1**
Bromus pubescens Muhl. ex Willd. (C3, H, I) **1**
Danthonia spicata (L.) Beauvis. ex Roemer & J.A. Schultes (C3, H, I) **14**
Dichanthelium acuminatum (Sw.) Gould & C.A. Clark var. *fasciculatum* (Torr.) Freckmann (C3, H, I) **15**
Dichanthelium boscii (Poir.) Gould & C.A. Clark (C3, H, I) **12**
Dichanthelium commutatum (J.A. Schultes) Gould (C3, H, I) **1**
Dichanthelium dichotomum (L.) Gould var. *dichotomum* (C3, H, I) **6**
Dichanthelium sphaerocarpon (Ellis) Gould (C3, H, I) **3**
Dichanthelium villosissimum (Nash) Freckman (C3, H, I) **1**
Elymus glabriflorus Scribn. & C.R. Ball var. *australis* (Scribn. & C.R. Ball) J.J.N. Campb. (C3, H, I) **5**
Lolium arundinaceum (Schreb.) J.J. Darbyshire (C3, H, X) **3**
Muhlenbergia capillaris (Lam.) Trin. (C4, H, I) **2**
Muhlenbergia cuspidata (Torr. ex Hook.) Rydb. (C4, H, EW, **T**) **2**
Muhlenbergia sylvatica Torr. ex Gray (C4, H, I) **2**
Panicum anceps Michx. (C4, Cr, ES) **2**
Panicum capillare L. (C4, Th, I) **2**
Panicum flexile (Gattinger) Scribn. (C4, Th, I) **14**
Panicum linearifolium (Scribn. ex Nash) Gould (C3, H, I) **13**
Paspalum leave Michx. (C4, H, I) **1**
Schizachyrium scoparium (Michx.) Nash (C4, H, I) **18**
Setaria glauca (L.) P. Beauvis. (C4, Th, X) **2**
Sorghastrum nutans (L.) Nash (C4, Cr, I) **16**
Sporobolus compositus (Poir.) Merr. var. *compositus* (C4, H, I) **14**
Sporobolus heterolepis (Gray) Gray (C4, H, EW) **1**
Sporobolus vaginiflorus (Torr. ex Gray) Wood, including varieties *ozarkanus* (Fernald) Shinners (C4, Th, I) and *vaginiflorus* (C4, Th, I) **18**
Tridens flavus (L.) Hitchcock (C4, H, I) **12**

SMILACACEAE

Smilax bona-nox L. (C3, Ph, ES) **16**

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